

Geologic Atlas of the City of Alexandria, Virginia and Vicinity—Overview

By Anthony H. Fleming, Licensed Professional Geologist, 2015

Background

The City of Alexandria is included in several small-scale, regional geologic maps and compilations, beginning with the first geological map of the Washington, D.C. area, by **Keith and Darton (1901)** and continuing forward through the water-resources investigations of **Johnston (1964)**, and culminating in a comprehensive study of the geology of Fairfax County and other parts of the DC metro area by the US Geological Survey during the 1970's and early 80's. The latter effort resulted in the publication of 1:24,000 (7.5-minute) geological maps of the topographic quadrangles partly or entirely in Fairfax County, including the Annandale Quadrangle (**Drake and Froelich, 1986**), which encompasses the far western part of Alexandria. The Alexandria Quadrangle, however, which encompasses the majority of the city, is not among the published geological maps. The city does appear on a 1:48,000 preliminary geologic compilation of Fairfax County (**Drake and others, 1979**), but the small scale of the map—the entire city appears within an area of approximately 6" x 6"—and the limited number and wide spacing of reference features on the base map limit its utility for many planning, engineering, and environmental applications. A subsequent compilation of maps by **Froelich (1985)**, which focuses on the geology and hydrology of the Coastal Plain of Fairfax County, is published at an even smaller scale (1:100,000), at which the entire city fits into a map area of 3" x 3". The City also appears on several even smaller-scale geological compilations (e.g., **Davis and others, 2001**; **Virginia Division of Mineral Resources, 1993**). The lack of availability of modern, detailed geologic maps has been a significant limitation for the City, considering both the need for such information and how varied the geologic conditions are.

The Geologic Atlas of Alexandria was created specifically to fill this need. In addition to compiling a substantial amount of previously-collected geological and historical data, the atlas incorporates a large amount of new geologic and engineering data collected specifically for this project. The entire city was physically mapped, either on foot or by vehicle, and geotechnical boring records from nearly 200 sites were collected. Many new exposures were visited, while the newly collected borehole information provided new insights into the subsurface distribution and environmental characteristics of different geologic units. The maps in this atlas were developed by combining the newly-collected information with the historical information into a series of databases and cross sections that enabled several kinds of interpretations to be made.

This approach differs from traditional regional geological mapping, which typically presents the interpretation of a given area on a single map. In the atlas, information is divided topically among several different maps (figure 1), including one devoted exclusively to showing the sources and distribution of geologic data. In this way, it is hoped that specific kinds of geologic information will not only be more easily accessible to users of the atlas, but also that the data used to compile it will be available to future studies in a readily understood, archival format. More than 40 new geologic units were identified and mapped during the project, and an entire map (plate 6) is devoted to showing hydrogeological features of significance to water supply, water quality, ecology, engineering, and general environmental interest. Another map (plate 7) focuses on slope stability and related geotechnical topics, while another section (Part 8) addresses seismic hazards, prompted in part by the 2011 Mineral, Virginia earthquake. Finally, the atlas is structured as an integrated online geological resource for the City, with the goal of making the information readily available to a variety of agencies, residents, businesses, researchers, the geotechnical and environmental consulting community, and others.

Contents

The atlas contains seven main maps and diagrams of the City of Alexandria and vicinity, referred to as plates, which are listed below. All of the plates are produced at a horizontal scale of 1:12,000, or one inch to one thousand feet, which is twice the resolution of a standard 7.5-minute USGS topographic map.

Plate 1: Map Showing the Distribution and Sources of Geologic Data

Plate 2 (A-O): Geologic Cross Sections

Plate 3: Map Showing Bedrock Geology, Topography of the Bedrock Surface, and Areas of Bedrock Exposure

Plate 4: Geologic Map of the Potomac Formation

Plate 5: Geologic Map Showing Surficial Geology, Landforms, and Major Areas of Artificially Modified Land

Plate 6: Map of the Piezometric Surface of the Cameron Valley Sand Member (Lower Aquifer of the Potomac Formation), and Other Aspects of Urban Hydrogeology

Plate 7: Slope Stability Map

In addition to the plates, which currently are rendered as static drawings (PDF's) using geologically correct color systems and nomenclature, the atlas includes a variety of other geological data, all of which is archived electronically. All of these documents can be accessed from the atlas [home page](#), and are organized as follows (file types listed parenthetically).

Databases and Subsurface Diagrams

- Alexandria exposures (MS-Excel)
- Alexandria geotechnical borings (MS-Excel)
- Alexandria USGS Wells (MS-Excel)
- Drillers logs collected by USGS for 5 deep wells (PDF)
- Alexandria geologic sample locations and field descriptions (MS-Excel)
- VDOT Woodrow Wilson Bridge-Capital Beltway Borings and Cross Sections: contains 17 fence diagrams (cross sections) in PDF format, generated directly from VDOT's former WWB-CB project website
- Schematic interpretive diagrams of geotechnical boring sites (PDF): contains cross-section diagrams summarizing the geologic interpretation for most of the geotechnical boring sites in the database

Expanded Explanations of Plates and Topics

- Plates 1 and 2: Geologic Data and Cross Sections-Expanded Explanation
- Plate 3: Bedrock Geology and Topography-Expanded Explanation
- Plate 4: Geologic Map of the Potomac Formation-Expanded Explanation
- Plate 5: Surficial Geology-Expanded Explanation
- Plate 6: Hydrogeology-Expanded Explanation
- Part 8: Overview of Tectonic Setting, Fault Systems, and Seismic Hazards

Expanded explanations are expanded versions of the map explanations, or legends, that appear on the plates. They are illustrated descriptions that provide additional information about the topic(s) encompassed by each plate. No expanded explanation was made for plate 7: the comprehensive publications on slope stability in nearby Fairfax County by **Stephen Obermeier** of the US Geological Survey, listed in the references, serve this purpose well. Additional observations concerning landslides and the geologic features and processes that contribute to them are included in the expanded explanation of specific map units in the Potomac Formation (Plate 4), and in relation to specific landforms discussed in the expanded explanation of Plate 5. Part 8 consolidates information from other parts of the atlas and outside publications in one section to address a timely geologic hazard.

How to Use This Atlas

Although all of the plates can and should be used together, each map also is designed to stand alone. In addition to the legend or explanation that appears on each plate, each plate is accompanied by a separate document, called an “expanded explanation”, where the map user can go to find additional information, illustrations, and explanation of the features shown, including a discussion of the geologic history and processes that led to the particular deposits or features shown on the map, and a topical bibliography highlighting previous geologic work in the area and other relevant sources of information on the topics at hand.

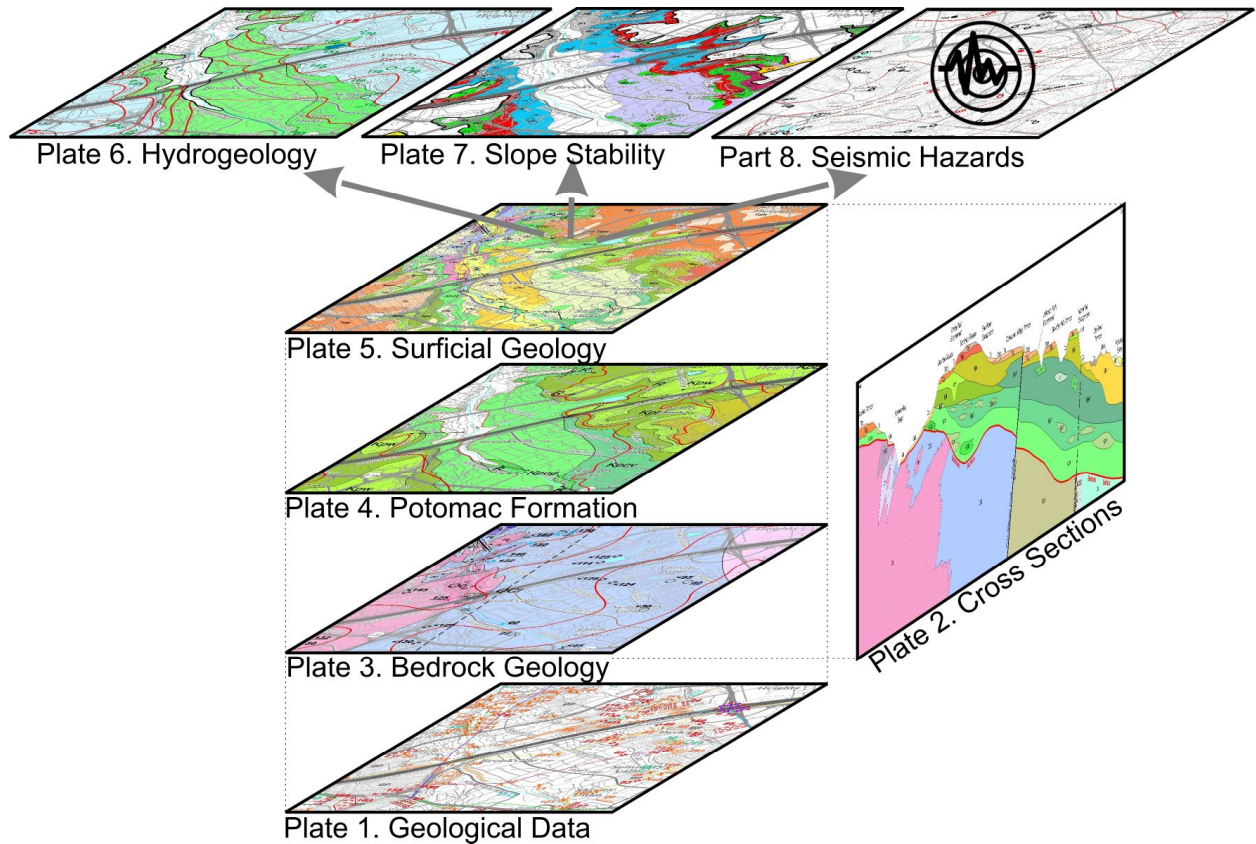


Figure 1. The Atlas can be thought of as a hierarchical stack of map layers, with each layer representing a group of allied strata or a particular aspect of local geology. Plates 3, 4, and 5 are basic geological maps. Plate 1 depicts the distribution and types of data the geologic maps are based on, while plate 2 represents the data in cross-sectional view, i.e., it allows the data and geologic interpretation to be visualized in the third dimension. Plates 6 and 7, and Part 8, on the other hand, are “derivative” maps and discussions, in that they use the underlying geologic information presented elsewhere in the atlas to derive interpretations of specific environmental topics, in this case, water and geotechnical engineering.

For most map users, plate 5 will be the most appropriate place to start. This map of “surficial geology” shows all of the different geologic units as they appear at the modern land surface and are distributed in the greater Alexandria landscape. These are the geologic materials that will be initially encountered by any activity or project involving the soil surface, for example, shallow excavations, surface-water hydrology, and horticulture. For many applications, this plate will be all that is needed.

Plates 2, 3, and 4 provide greater detail about the subsurface. Broadly speaking, the City can be regarded as a relatively regular series of geologic strata and horizons that have been gently tilted to the southeast, and which have been covered at places by a host of less

regular alluvial and slope deposits associated with the valleys of modern streams and the many hillsides that dominate the City's landscape. Plate 5 shows all of these kinds of deposits as they crop out at the surface. Since many of the surficial deposits are relatively thin, however, it is sometimes useful to know what lies underneath.

Plate 4 depicts the geology of the Potomac Formation, the major system of Coastal Plain strata that immediately underlies the surficial deposits in most places in the City. Plate 4 was created by stripping all of the younger surficial deposits off of plate 5 to reveal the strata below. The geologic map on plate 4 is based on a combination of outcrop data (as evident from plate 5, the Potomac Formation crops out at the surface at many places) and boreholes that penetrate beneath the veneer of surficial deposits to reveal the underlying strata. The Potomac Formation contains both sandy, clayey, and mixed-texture map units, hence its characteristics at any given location are of utmost importance for both ground-water resources and engineering. The amount of subsurface data available during this project allowed the Potomac Formation to be interpreted and subdivided at a level of detail not previously possible; major bodies of water-bearing sand and unstable clay, for example, were able to be delineated fairly reliably in many parts of the City.

The Potomac Formation, in turn, overlies the bedrock, which consists of ancient igneous and metamorphic rocks of the Piedmont, and which has been complexly folded and deformed. Bedrock crops out only in the far western part of the City, in the vicinity of Holmes Run Gorge, but it is present everywhere beneath the younger strata, and contains many structures and features having potential significance for ground water, modern seismicity, and other applications. The buried bedrock surface also is a fundamentally important stratigraphic horizon in and of itself, and has major engineering, hydrogeologic, and seismic significance. Plate 3 shows the bedrock geology and structure throughout the City, and is what you would see if everything above the bedrock surface was stripped off. In the large part of the City where bedrock is deeply buried beneath younger deposits, the geology and structure were deduced from a few deep boreholes, and from regional geophysical data available from the USGS, which typically strongly reflects bedrock structure and extends into adjacent areas where the bedrock is well exposed.

Plate 2 depicts a series of geologic cross sections that provide a three-dimensional view of the subsurface. Fifteen cross sections were constructed throughout the city, using a combination of borehole, water-well, and outcrop data to reconstruct the vertical profile of rocks, sediments, and ground water levels along each section line. The cross sections are oriented so that some of them follow the regional southeastward dip of the strata, whereas others run at various angles to the dip. Some of the sections follow major thoroughfares, such as Seminary Road, Duke Street, and Shirley Highway, while others encompass more offbeat places, such as the natural areas near the far northwestern city limits. Every quadrant and major neighborhood of the City is encompassed in at least one cross section. Cross section layout is shown in detail on plate 1. Each cross section constitutes its own plate (2A – 2O), hence the cross sections have their own home page from which each individual section can be accessed.

For water-resources and environmental applications, plate 6 provides additional hydrogeologic information that supplements the other maps, for example, the locations of wells and springs, the types and locations of wetlands, and the direction of ground-water flow in the City's major aquifer system. Plate 7 is similarly focused on a specific topic, namely slope stability. By relating subsurface geologic conditions to slope pitch, the map broadly ranks the City's hillsides according to their susceptibility to landslides; the map also identifies areas where expandable soils are likely to be present, as well as places where recently active slope failures have been observed. Both of these derivative maps have broad application as educational and planning tools, but their main audience will likely be the

particular subsets of users who are actively addressing water or geotechnical issues, either on their own properties or in a professional capacity.

Part 8 provides an overview of seismic hazards. Though not technically an “expanded explanation”—there is no “plate 8” in the atlas—this well illustrated section can also be thought of as a derivative of the other geologic data, because it brings together earthquake-related information both from other parts of the atlas and from a variety of outside sources. This section, which includes a catalog of known faults and other “suspect” structures in the map area, should be of interest to both professionals who deal with seismic risk and the general public.

Finally, plate 1 depicts the data that were used to construct the atlas. It shows the distributions and sources of each type of data, including surface exposures, historical water wells, geotechnical borings, excavations, and others. Each kind of data is referenced by a specific numerical identifier, and all data points are catalogued by type in the databases noted above. Each spreadsheet entry provides a brief description of the key geologic features or information associated with each data point. The map of geologic data is particularly useful for getting a sense of the reliability of geologic contacts and other interpretations shown on the maps: reliability is greatest in places having a large concentration of data points, and least where data are sparse. Along with the associated databases, plate 1 also acts as an archive of the data collected for this study, and may prove useful in the future to others who are carrying out geological research or other types of investigations benefitting from geologic information. Here, it might be noted that any geologic map is basically a “progress report”, and is likely to be updated or entirely superseded by new maps in the future as new data emerge and ideas evolve. A well-organized archive of historical geological data and observations can only improve that process, considering the transient nature of exposures, boreholes, and other types of data.

Map Area and Base Map

In addition to the City of Alexandria, the map area also includes portions of the adjacent jurisdictions. There are several reasons the map area was expanded beyond the City limits: 1) the boundaries of the City are largely defined by waterways and streets, none of which are particularly straight; this results in a polygon that would be highly irregular if limited strictly to the City. Expanding the map area produced a simpler rectangular polygon; 2) in some cases, stellar exposures of geologic formations, landforms, or other features are located a short distance outside of the City; 3) finally, and most importantly, geologic features and strata do not respect political boundaries. Ergo, including the surrounding area allowed a more complete and accurate depiction of local geology. Likewise, the City’s major watersheds are multi-jurisdictional.

The base map for the atlas is part of the **U.S. National Map** available from the U.S. Geological Survey. This online resource provides up-to-date seamless topographic and planimetric coverage of the coterminous United States at a scale of 1:24,000, and supercedes the familiar 7.5-minute topographic quadrangle maps many people are familiar with. The map area of the atlas encompasses portions of the Alexandria and Annandale 7.5-minute quadrangles and is depicted at a 10-foot contour interval.

Terminology and Conventions

An attempt was made to minimize the use of highly technical jargon in the atlas, but geology being a technical science, some use of terminology specific to both the science and the geology of Alexandria is unavoidable. Specialized technical terms that may not be familiar to readers are typically explained in the text where they are first used in the expanded explanations. In addition, the atlas includes a glossary of geologic terms listed in

alphabetical order. Users can access the glossary in two ways: specific terms included in the glossary are underlined and italicized, generally where they are first used in a document. Hovering the cursor over these “rollover” terms causes the definition to appear next to the term (figure 2). Alternately, users can simply open the glossary in a separate window from the link on the atlas home page, and scroll through it as needed.

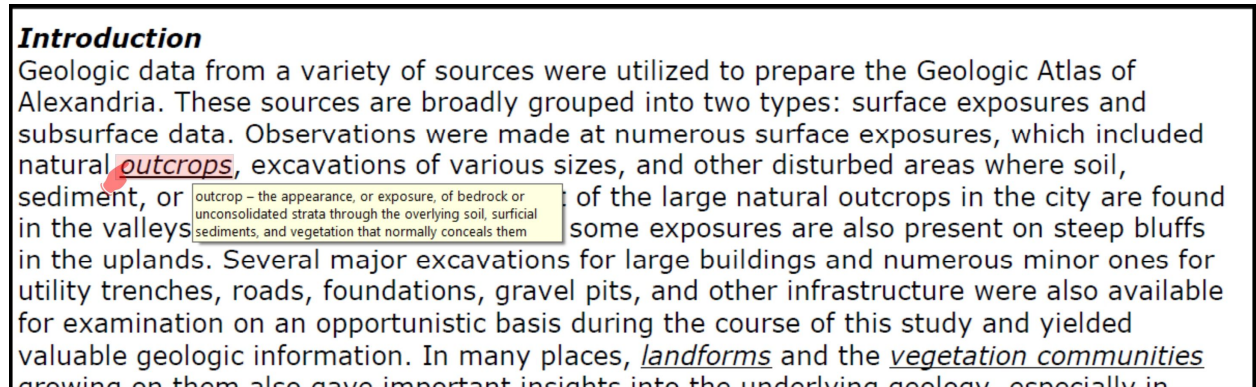


Figure 2. Example of the rollover function in atlas documents. When the cursor hovers over an italicized, underlined term in the text, the definition appears in the box.

References cited in the atlas are accessed in a similar manner. Citations in the text appear in green (e.g., **Fleming and others, 1994**); like a glossarized term, hovering the cursor over a citation causes the full reference to appear on the screen adjacent to the citation in the text. Further, a complete list of references cited in any given section of the atlas appears at the end of the document, and many of these listings are hotlinked to a downloadable electronic version of the reference. It should be noted that some references are unavailable electronically and can be obtained only as print copy from a library, while some of the electronic references (especially journal articles) reside behind a paywall, though the abstract is almost always available free of charge. Finally, a comprehensive bibliography containing all of the references cited in the atlas is available either from the atlas home page by clicking on the “Bibliography” button, or by clicking on the “References” section heading at the end of the document.

Geology deals with a vast amount of time, measured in many millions of years. The Potomac Formation, for example, was deposited during the early Cretaceous Period, which began some 144 million years ago, whereas the oldest crystalline rocks in Alexandria may be greater than 500 million years old. Ages of rocks, sediments, and landforms are typically stated in terms of millions of years, using the abbreviation “ma”, for example, 144 ma. Likewise, the Pleistocene epoch, or Ice Age, spans the last 2.6 million years, and is divided into several stages and substages whose ages are measured in thousands of years, abbreviated as, for example, 150 ka. Both of these abbreviations appear frequently in the Atlas. One other useful abbreviation is “ybp”, which stands for “years before present” and is used in connection with Pleistocene events and stages.

This atlas uses links to allow navigation between the different maps and documents, as rollover terms to provide definitions and citations, and to connect users to outside sources of geologic information. The number of links is minimized to avoid cluttering up the atlas and creating distractions. References, for example, are linked to the bibliography no more than once per page, typically where first introduced on the page. Links are also color coded to signify different destinations: **green links** lead to another place in the same document, or in the case of references, signify a rollover citation; **blue links** open another document in the atlas; and **red links** open an external website or document.

Important! Some features may not be fully functional in all browsers!

If you are unable to access certain features in your browser, the simplest solution is to download the document and view it in a PDF reader like Adobe Acrobat. In addition to providing full functionality, viewing the atlas in a PDF reader provides optimum resolution of the maps and illustrations.

Acknowledgments

This project succeeded because of the support and assistance from several City agencies and individuals. Major support during the early stages of the project was provided through the Park Planning Division of the Department of Parks, Recreation, and Cultural Resources (RPCA), and more recently, via the Natural Resources Division of RPCA. Rod Simmons, Robert Taylor, and John Walsh of that group were closely involved with the project throughout and provided invaluable technical and logistical support. Rod's encyclopedic knowledge of the City and surrounding areas led to many field outings to interesting and important geologic, ecologic, and historical sites, and on numerous occasions, he acted as chauffeur and field guide while the author made observations of the Alexandria landscape. Many of Rod's photographs also grace the pages of the atlas. Ken Simmons, formerly of the same section, provided essential guidance to key field localities and vegetation communities.

Several other City agencies generously provided access to their files of geotechnical and engineering reports, and to their facilities, including the Department of Transportation and Environmental Services (T&ES), Planning and Zoning, and Alexandria Public Schools. The assistance of Shanna Austin, T&ES site plan coordinator, Greg Tate, former T&ES site plan coordinator, and Kendra Jacobs, Senior Planner, is gratefully acknowledged. Mark Krause, Director of Facilities for Alexandria Public Schools was instrumental; his encyclopedic knowledge of past school projects led to many geotechnical reports that provided crucial data in places otherwise lacking subsurface information. Ray Tudge, Thomas Wong, and Carlin Hall of VDOT facilitated the acquisition of major sets of geotechnical borings for the Capital Beltway and Shirley Highway. Thanks also go to Brett King and Jason Agatone of the City's GIS Division for providing detailed topographic and orthophoto maps of the field area, and to Eugene Brodetski of the Natural Resources Division for major assistance with the website.

Finally, the author gratefully acknowledges the U.S. Geological Survey for its vast and indispensable library of publications on the Nation's and region's geology and water resources. Much of the information compiled in this atlas is the direct result of decades of dedicated work in the region by various USGS geologists, many of whom I know or knew personally.

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